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PREDICTION OF RECOVERY FROM UPPER EXTREMITY PARALYSIS AFTER STROKE BY MEASURING EVOKED POTENTIALS

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ABSTRACT. Paralysis of the upper extremity is a severe motor impairment that can occur after stroke. Prediction of recovery from paralysis is difficult and is primarily based on subjective clinical evaluation. However, the integrity of the sensorimotor system can be assessed objectively and quantitatively by measuring evoked potentials. In this retrospective exploratory study, we evaluated the predictive value of motor and somatosensory evoked potentials for recovery from paralysis of the upper extremity. Motor and somatosensory evoked potentials were recorded in 29 patients who had had their first-ever infarction in the territory of the middle cerebral artery and who exhibited paralysis of the upper extremity. At follow-up, seven patients showed motor recovery. The evoked potential data were dichotomized into present or absent and related to the occurrence of motor recovery. Analysis revealed a significant association between the presence of evoked potentials early after stroke and the observed occurrence of motor recovery. These results suggest strongly that evoked potentials predict the occurrence of motor recovery of upper extremity paralysis in patients suffering from first-ever infarction in the territory of the middle cerebral artery.

Key words: MEPs, motor recovery, SEPs, stroke, upper extremity.

INTRODUCTION

Recovery after stroke is influenced by a variety of biological and environmental factors (3), and recovery profiles show a high interindividual variability. To date, there have been no objective and reliable instruments available to predict recovery after stroke.

A distinction is usually made between spontaneous recovery, due to the self–organizing capacity of the brain, and the development of novel adaptive control strategies, as a result of therapy and learning. Spontaneous recovery results, particularly in the (sub)acute phase, in a substantial recovery from the sensorimotor impairments and cognitive disorders. Adaptive control strategies may play a role in the post-acute period (3). Thus, the recovery of functional skills may be attributable to both neurological recovery and behavioural compensation.

This study focuses on the spontaneous neurological recovery of patients with upper extremity paralysis after their first-ever stroke. Complete paralysis of the upper extremity is frequently seen after infarction in the territory of the middle cerebral artery, and is a severe condition which may be complicated by subluxation, shoulder pain or even shoulder-hand syndrome. If no or poor motor recovery occurs, the patient will have serious disabilities. However, even if motor recovery occurs, the patient must receive adequate training in order to optimize functional abilities. Inadequate training may lead to a learned disuse syndrome (31).

Early prediction of recovery from upper extremity paralysis after stroke remains a difficult issue. Until now, there were no clinical tests which could accurately predict the rate of motor recovery. The severity of the initial motor deficit is usually used as the most important predictor (4, 7, 27, 28, 36). Yet somatosensory evoked potentials (SEPs) and motor evoked potentials (MEPs), which provide information about the integrity of the somatosensory and the motor pathways, may provide more objective and reliable data in this context, when measured in the subacute phase after stroke. SEPs have been extensively studied in stroke patients (12, 18, 21, 23, 24, 35), and more recently MEPs have also been studied in this population (1, 2, 5, 6, 8, 11, 13, 15, 19, 20, 22, 25, 32, 33). Earlier studies have indicated a powerful predictive value of SEPs (21, 23) and MEPs (13, 20, 25) for motor recovery of the upper extremity. Hendricks et al. (21) used SEPs to predict the occurrence of motor recovery in 7 stroke patients, who exhibited upper extremity paralysis. The prediction based on the SEPs was correct in all cases but one. Further examination of this patient provided evidence for a demyelinating disease. Dominkus et al. (13) studied electrical motor evoked potentials in relation to motor recovery of the upper and lower extremity in 33 stroke patients. Eleven patients exhibited initial paralysis of the upper extremity, of whom 6 patients had absent MEPs. No motor recovery occurred in 4 of them, 1 patient died and 1 patient showed minimal recovery. Of the 5 patients with present MEPs, 1 died and 4 experienced moderate to good recovery. Macdonell et al. (25) recorded SEPs and MEPs (electrical stimulation) in 19 stroke patients exhibiting different degrees of hemiparesis. Seven patients showed complete paralysis of the arm; both SEPs (N20) and MEPs were absent in these patients. None of them experienced any motor recovery. Arac et al. (2) evaluated the role of MEPs (abductor pollices brevis and tibialis anterior muscles) in predicting functional motor recovery (arm and leg) in 27 acute stroke patients. Six patients exhibited paralysis of the upper extremity and had absent evoked potentials (abductor pollices brevis muscles). Three of these six patients died, three showed considerable motor recovery. The authors concluded in contrast with other studies that MEPs had no value in predicting the outcome of hemiparesis or hemiplegia.

We assessed the predictive value of evoked potentials for recovery from paralysis of the upper extremity by reviewing data for motor and sensory evoked potentials in a historical cohort of stroke patients.

METHODS

Subject selection

The historical cohort consisted of all patients admitted consecutively (Department of Neurology, Medisch Spectrum Twente) over a 26-month period (32). On admission, all patients underwent a standard clinical and neurological examination. Patients were included only if the current episode was the first–ever infarction in the territory of the middle cerebral artery, confirmed radiologically (CT-scan or NMR), and if they had been admitted within 24 hours of onset of symptoms. Patients gave their informed consent before they were included in the study. They were excluded if they had a history of craniotomy, epilepsy, cardiac prosthetic valve or pacemaker implantation.

The initial motor scores for the upper extremity of these patients were reviewed. Motor impairments of the upper extremity were classified as either paralysis or paresis. Paralysis was defined as no voluntary motor action in the shoulder, arm and hand. Only those patients who exhibited paralysis at admission or who developed paralysis within the first three days after admission were examined at follow-up. Patients were excluded if they had died or had another stroke within 3 months.

In the period March 1992 to May 1994, 69 patients were initially included. However, 7 patients were excluded later because CT scans revealed a hemorrhage, more than one or no infarct (four patients), wrong location (two patients), and 15 patients had to be excluded for other reasons: 11 patients died within 3 months of the stroke, no follow-up data were available in 3 patients, 1 patient had another stroke within 3 months. Thus, 47 patients were eligible for this study, of whom 29 (15 females and 14 males, mean age 63.7 [range 22–85] years) exhibited paralysis of the upper extremity at admission or who developed paralysis within 3 days after admission. At follow-up, 1 to 4 years post-stroke (mean 2.4 years), 20 patients with initial upper extremity paralysis were alive and available for clinical evaluation. The motor recovery of the patients who had died was assessed by reviewing the medical records.

Neurophysiological methods

Evoked potentials were recorded on day 3 or 4, 6 weeks and 3 months post-stroke. For cortical magnetic motor stimulation a Medicor Magstim 200 magnetic stimulator was used with a 70-mm coil, and for cervical stimulation a twin coil was used. Stimuli without facilitation were given with increasing intensity until a response of maximal amplitude was obtained. Muscle responses were recorded with surface electrodes taped over the abductor digiti quinti muscle, using an EMG Nicolet Viking EMG recording system. The computed central conduction time (CCT), i.e. the time difference between cortical and cervical stimulation, was compared to normal values (14) and to values for the contralateral side. MEPs were scored as normal, delayed (difference of more than two standard deviations) or absent. Ipsilateral responses were registered when present.

SEPs were recorded after median nerve stimulation on both sides. We used a Nicolet Pathfinder system. Four averaging channels were used to record SEPs at the scalp (right C3-A2, left C4-A1), the neck (5th cervical spinal process), Erb's point and the elbow. The bandpass was 5–3000 Hz, 30–3000 Hz, 100–3000 Hz and 100–3000 Hz, respectively. SEPs latency values were compared to those for the contralateral side and to normal data. SEPs were scored as normal, delayed (difference of more than 2 standard deviations) or absent.

Assessment

At follow-up, all patients with initial upper extremity paralysis were evaluated. Motor recovery was defined as any voluntary motor action in the affected shoulder, arm or hand. If motor recovery had occurred, the exact motor status was evaluated by means of the Fugl-Meyer Motor Assessment (17). This cumulative numerical scoring system is based on the sequential stages of recovery observed in hemiplegic patients (10, 34). In this study, the upper extremity part of the assessment was used with a maximum of 66 points. In accordance with the original assessment, reflex activity, motor functions, coordination and speed were scored under standardized test conditions. If patients were not available for clinical examination, the medical records were reviewed.

Analysis

In the analysis both the MEPs and the SEPs were dichotomized into present (delayed or normal) or absent. This dichotomy forms the basis for outcome studies using evoked potentials (11, 13, 20, 35). The MEPs and SEPs data were related to evidence of motor recovery at follow-up. The relationships are illustrated by "2×2" contingency tables according to Fletcher et al. (16). The chi-square test was used to test the null hypothesis that evoked potentials, detected soon after stroke,

Table I. *The motor scores of the upper extremity at follow-up, in relation to evoked potentials, recorded soon after the stroke*

Patient No.	Motor score (FMA)	MEPs	SEPs
3	–	Absent	Normal
17	–	Delayed	Absent
18	–	Normal	Normal
37	12	Absent	Absent
40	66	Normal	Normal
51	66	Normal	Normal
65	66	Delayed	Normal

MEPs: motor evoked potentials; SEPs: somatosensory evoked potentials.

are not related to the occurrence of motor recovery. Odds ratios were calculated to express the change in motor recovery when evoked potentials were detected.

RESULTS

On clinical evaluation, three patients showed excellent motor recovery and one patient showed minor improvement; three patients were not evaluated, because they had died, but their medical records indicated that they had shown motor recovery. The motor scores at follow-up in relation to evoked potentials are presented in Table I. MEPs were present in five of the seven "recovery" patients and in none of the "no recovery" patients. SEPs were present in five of the seven "recovery" patients and in six of the "no recovery" patients.

The relationships between MEPs and SEPs and the occurrence of motor recovery are summarized in Tables II and III. The chi-square values for MEPS and SEPs were 15.29; df = 1; $p = 0.0001$ and 4.39; df = 1; $p = 0.0340$, respectively. The null hypothesis could be rejected, as evoked potentials detected soon after stroke, were significantly associated with motor recovery. The odds ratios for MEPs and SEPs were 46.00 (95% ci 6.75–313.30) and 6.66 (95% ci 1.13–39.26), respectively.

Table II. *The relationship between motor evoked potentials (MEPs) recorded in the subacute phase after stroke, and motor recovery of the upper extremity*

	Motor recovery +	Motor recovery –	Total
MEPs +	5	0	5
MEPs –	2	22	24
Total	7	22	29

Table III. *The relationship between somatosensory evoked potentials (SEPs), recorded in the subacute phase after stroke, and motor recovery of the upper extremity*

	Motor recovery +	Motor recovery –	Total
SEPs +	5	6	11
SEPs –	2	16	18
Total	7	22	29

When calculating the odds ratio for MEPs, we added the value of 1 to each cell since one of the cells of the fourfold table was zero.

Twenty patients were reassessed neurophysiologically at 6 weeks and 3 months. Nine patients refused to undergo the second and/or third assessment. MEPs improved over time in four "recovery" patients, either from no response to delayed CCT or from delayed CCT to normal. None of the "no recovery" patients showed any improvement of the MEPs. SEPs improved in seven patients, two of whom exhibited motor recovery.

Ipsilateral responses were initially present in six patients and were detected in three other patients at the second assessment. Only one "recovery" patient showed ipsilateral responses.

DISCUSSION

We reviewed the initial motor status of a defined cohort of patients who had had their first-ever brain infarction in the territory of the middle cerebral artery, and in whom both somatosensory and motor evoked potentials were recorded in the subacute phase and at 6 weeks and 3 months after the stroke. Only those patients with initial paralysis of the upper extremity were clinically evaluated at follow-up. We found a close association between evoked potentials, recorded soon after the stroke, and the occurrence of motor recovery in patients who survived the first 3 months and who did not have another infarction.

The safety of magnetic stimulation has been assessed in several studies (9, 30). Transcranial magnetic stimulation appears to be a safe method. Side effects have been described especially in epileptic patients after rapid-rate transcranial magnetic stimulation (26). However, in our study we only used single stimuli. Furthermore, we excluded those patients who had a history of epilepsy.

Despite the retrospective character of this study, the results strongly suggest that motor and somatosensory evoked potentials predict the occurrence of motor recovery from upper extremity paralysis. Earlier studies (13, 20, 21, 23, 25) already indicated such a relationship. However, in contrast to most other studies, we focused on patients who exhibited upper extremity paralysis. Only Arac et al. (2) reported other findings, probably because of the differences in patient selection and timing of neurophysiological assessment.

One can debate about the prognostic value of the somatosensory evoked potentials in this context. Hendricks et al. (21) addressed this point in an earlier paper. Since there is a close anatomic relation between the somatosensory and the motor systems of the upper extremity, SEPs may be a sensitive indicator for the integrity of both systems. However, the integrity of the motor systems can be assessed more directly by motor evoked potentials, which was confirmed in the present study.

Neurophysiological reassessment 6 weeks and 3 months after the stroke showed changes in only nine patients. Improvement of the MEPs was found in four patients, and was accompanied by motor recovery. There was no clear relation between the presence or the occurrence of ipsilateral responses and motor recovery of the upper extremity in our study group. This is in accordance with an earlier study (29).

Several issues need to be investigated in a prospective study. The predictive value of MEPs in patients exhibiting different grades of paresis is not clear. Subgroups of patients should be identified, who would benefit most from an early prediction of motor recovery based on MEPs. Furthermore, repeated evaluation of neurophysiological impairments may increase our knowledge of the processes associated with recovery following brain damage.

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